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POLARIZED HEAVY QUARK PHOTOPRODUCTION IN NEXT TO LEADING ORDER

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Results of our next-to-leading order analytic calculation for longitudinally polarized photoproduction of heavy quarks are presented. Certain differential cross sections and the corresponding asymmetries are computed for energy ranges accessible to CERN and HERA. We argue that determination of the polarized gluon distribution is possible at both places: at HERA certain acceptance cuts are necessary.

Deep Inelastic Scattering (DIS) of longitudinally polarized particles has been very useful in extracting the polarized valence distributions. However, it is quite limited in extracting the polarized gluon distribution Δg . Much was already said at this Workshop about the importance of knowing Δg , and there is no need to talk about it any further. In order to extract Δg with a good accuracy one needs experiments involving longitudinally polarized reactions dominated by subprocesses with initial gluons.

One such reaction is the inclusive polarized photoproduction of heavy quarks:

$$\vec{\gamma} + \vec{p} \rightarrow Q(\bar{Q}) + X, \quad (1)$$

which at leading order (LO) proceeds through the subprocess:

$$\vec{\gamma} + \vec{g} \rightarrow Q + \bar{Q} \quad (2)$$

There are several experimental proposals on the subject in various stages of approval [1].

Next-to-leading order corrections (NLOC) are very important for several reasons: a) The leading order estimates depend strongly on the a priori unknown renormalization and factorization scales; in general the NLOC reduce this uncertainty. More precisely, going to one level higher in the strong coupling α_s may reduce the uncertainty by order α_s ; b) NLOC may be large and negative in some regions of phase space, making cross sections small and difficult to measure; c) At NLO, subprocesses unrelated to the LO ones could come into play. In principle, the contribution of such subprocesses could be significant in

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certain important parts of phase space and this could affect even the shape of the final cross sections. However, admittedly in the present case, the subprocesses

$$\vec{\gamma} + \vec{q}(\vec{q}) \rightarrow Q + \bar{Q} + q(\bar{q}), \quad (3)$$

(q =light quark) which belong to this class, make a relatively small contribution. The same holds for the corresponding unpolarized subprocesses [2], as well as for other such subprocesses (taken separately) we have studied [3].

Nevertheless, irrespective of relative sizes, this talk presents a *complete* NLO calculation of polarized photoproduction of heavy quarks. Some results, in a very preliminary stage, have already been reported [4].

An independent calculation of NLOC has appeared [5], and we subsequently comment on it.

Let $M_i(\lambda_1, \lambda_2)$ be the amplitude of any of the contributing subprocesses and λ_1, λ_2 the helicities of the initial partons. Then unpolarized and polarized, cross sections correspond to the quantities:

$$\frac{1}{2} \Sigma [M_i(++) \overset{*}{M}_j(++) \pm M_i(+-) \overset{*}{M}_j(+-)], \quad (4)$$

where Σ denotes summation over the helicities and colors of the final particles and average over the colors of the initial. Note for the unpolarized case one usually averages over $n-2$ spin degrees of freedom for every incoming boson, which amounts to multiplying (4) by $2/(n-2)$ for each initial boson.

Note that the Abelian part of the NLOC to our dominant subprocess (2) is of interest in itself, for it determines the NLOC to $\vec{\gamma} + \vec{\gamma} \rightarrow Q(\bar{Q}) + X$ [6, 7]. Note also that, as it was already done in [6], a calculation of NLOC for a polarized reaction and the corresponding unpolarized one can be done by simply using different projection operators.

Our regularization scheme is dimensional reduction (RD) properly supplemented by finite counterterms [6] and conversion terms [8] (see also below). We work in the Feynman gauge.

In determining the loop contributions, the renormalization of the heavy quark mass and wave function were carried on shell. Furthermore, in our scheme, the contribution of a heavy quark loop in the gluon self-energy is subtracted out, i.e. the heavy quark is decoupled. This is consistent with parton distributions of which the evolution is determined from split functions involving only light quarks.

Our loop contributions have been determined by REDUCE [9] and to some extent by FORM [10]. Tensor integrals have been reduced to scalar ones. It is worth noting that, in general, the coefficients of pole terms $1/\varepsilon^2$ and $1/\varepsilon$ for separate graphs are not proportional to the LO term; only their sums are.

Gluon Bremsstrahlung contributions of e.g. $\vec{\gamma} + \vec{p} \rightarrow Q + X$ are determined, as usual, by working in the c.m. frame of \bar{Q} and g (Gottfried-Jackson). Many necessary n - and 4-dimensional integrals are given in [11] and the rest were derived by ourselves [8]. Factorization terms are added in the usual way, and the cancellation of the loop $1/\varepsilon^2$ and $1/\varepsilon$ singularities is a good indication of the correctness of our results.

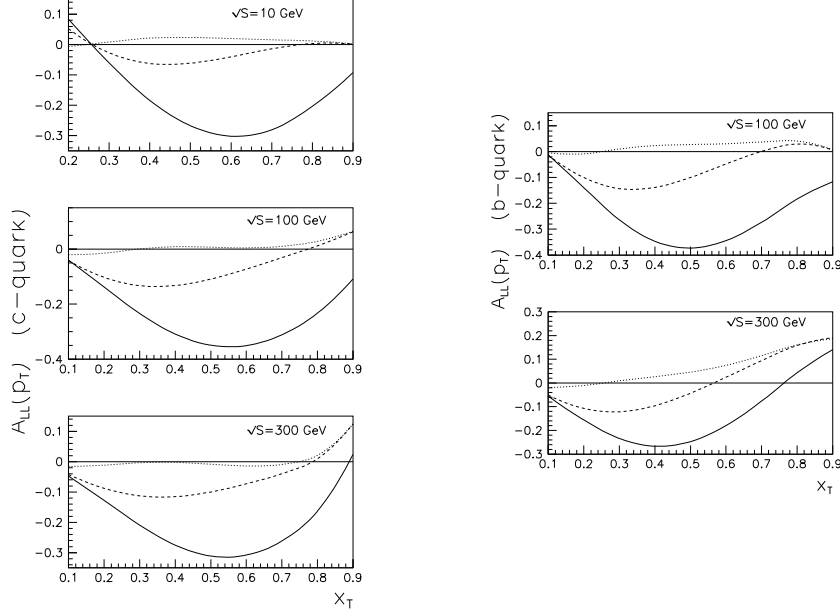


Figure 1: Differential asymmetry as defined in the text for three sets of GS polarized pd. Solid lines: set A, dashed: set B, dotted: set C.

Here we leave out a resolved γ component; this, as well as an estimate of the anticipated experimental errors, is given in [8].

Our cross sections are convoluted with parton distributions evolved via two-loop split functions. However, polarized split functions have been determined in the modified t'Hooft-Veltman (HV) scheme [12]. Thus, conversion terms were necessary to transform our results to the HV scheme.

We now present some numerical results for the polarized differential cross sections: $\Delta d\sigma/dp_T$ and $\Delta d\sigma/dy$, where p_T and y the transverse momentum and c.m. rapidity with respect to the photon of a heavy quark of mass m . For the renormalization (μ) and factorization (M) scales we take: $\mu^2 = M^2 = p_T^2 + m^2$ for $\Delta d\sigma/dp_T$ and $\mu^2 = M^2 = 4m^2$ for $\Delta d\sigma/dy$. With \sqrt{S} the c.m. energy of the colliding particles we define $x_T = 2p_T/\sqrt{S}$. We use the three sets of polarized parton distributions (pd) of [13], which mainly differ in Δg : Sets A and B differ in the size of Δg , set C also in the shape. Our asymmetries are defined as follows:

$$A_{LL}(p_T) = \frac{\Delta d\sigma/dp_T}{d\sigma/dp_T}, \quad A_{LL}(y) = \frac{\Delta d\sigma/dy}{d\sigma/dy} \quad (5)$$

For the unpolarized cross sections we use the pd of [14]. Our figures are for three energies: $\sqrt{S} = 10$ GeV (COMPASS and SLAC) and $\sqrt{S} = 100$ and 300 GeV (HERA).

Fig. 1 presents our NLO $A_{LL}(p_T)$ for $Q = c$ and $Q = b$ quark. Clearly, in general, sets A, B and C lead to $\Delta d\sigma/dp_T$'s well separated. Also note that, in general, at small x_T ,

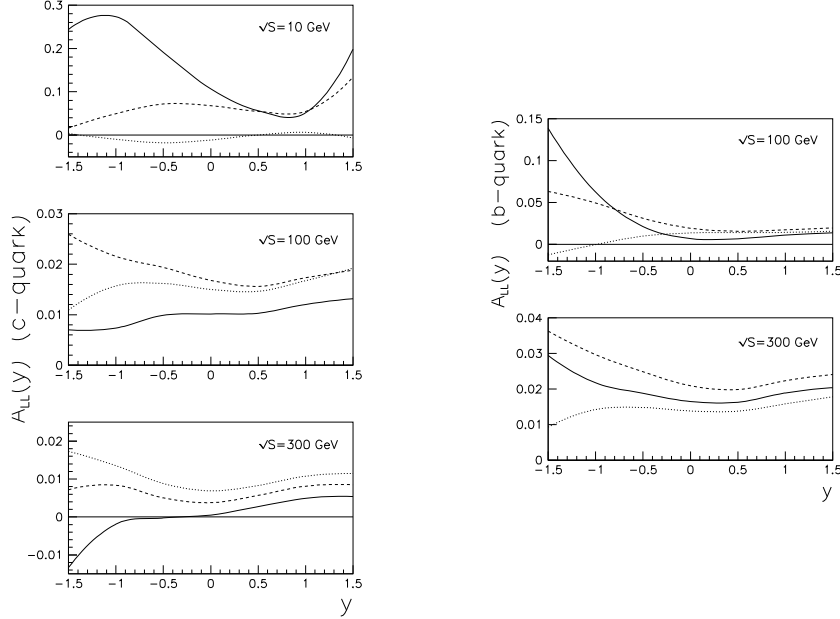


Figure 2: Rapidity differential asymmetry as defined in the text for three sets of GS polarized pd. Lines as in Fig. 1.

s $A_{LL}(p_T)$ are relatively small; exception is $\sqrt{S} = 10$ GeV, when $A_{LL}(p_T)$ stay relatively sizable. On the other hand, at low x_T both the polarized and unpolarized cross sections are relatively large; this is particularly true for the unpolarized ones at HERA. Then, at HERA, at small x_T , $A_{LL}(p_T)$ are very small, as was indeed found in [5].

Fig. 2 presents $A_{LL}(y)$ and Fig. 3 the sizes of $\Delta d\sigma/dp_T$ and $\Delta d\sigma/dy$. In the later we do not plot results for $\sqrt{S} = 300$ GeV as the cross sections are too small to be measured. For c-quark it seems that $\Delta d\sigma/dp_T$ is measurable up to $x_T \simeq 0.4$. Also, at $\sqrt{S} = 10$ GeV, looking at Fig. 2 and Fig. 3 we see that in the range $1 \leq y \leq 1.5$ both $A_{LL}(y)$ and $\Delta d\sigma/dy$ are quite sizeable, so useful information on Δg could well be obtained.

$\Delta d\sigma/dy$ of Fig. 3 show also that heavy quarks are mainly produced forwards with respect to the (incoming) photon.

As we discuss in detail in [8], in general, we agree with [5]. Nevertheless, perhaps on the basis of the smallness of HERA A_{LL} at small x_T , Ref. [5] concludes that HERA is rather useless in specifying Δg . Here we argue that it may be not so: On the basis of Fig. 1, reconstruct events and select only those with, say, $x_T > 0.2$; in other words, carry integrations of $\Delta d\sigma/dp_T$ over some cut phase space. This may well enhance the resulting A_{LL} .

Of course, to reach a definitive conclusion, more work is needed, including an estimate of the corresponding errors.

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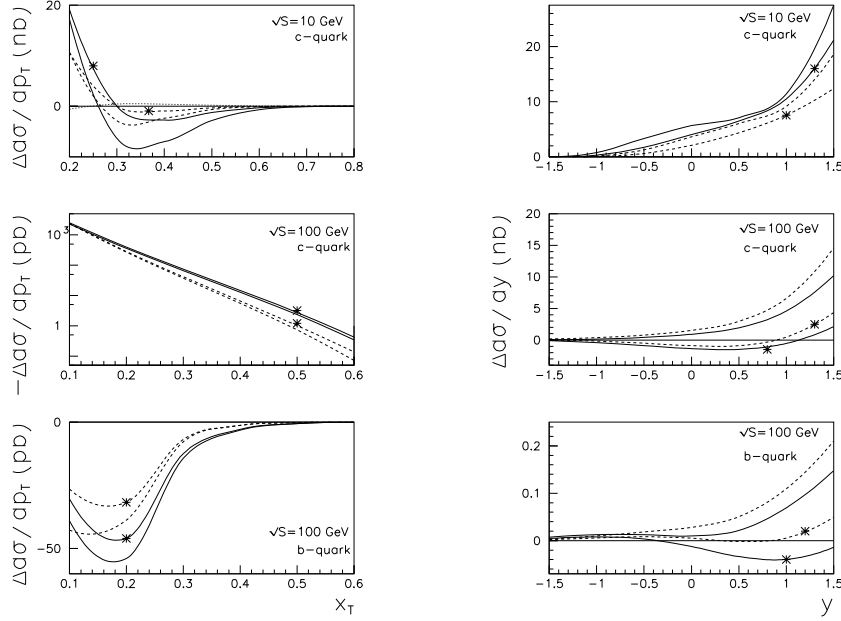


Figure 3: Polarized cross sections for two sets of GS polarized pd. Solid lines: set A, dashed: set B, dotted: contribution due to the light quark subprocess (3). Leading order results are marked with stars.

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